

## EDITORIAL

### Flash floods in Uttarakhand Himalaya: Reasons and remediation

The Himalayan region has been suffering from different kinds of climate-induced geological hazards, out of which the flash floods have been often due to one of the causes of erratic rainfall or cloudbursts, ice/snow avalanches, glacial lakes outburst, landslide lakes outburst, fluvial extremes, abrupt river incisions, reservoir-dam failure, or a combination of two or more of these. The floods have instigated loss of lives and livestock, and/or damage to properties and structures leading to disasters of variable magnitudes. The aspects that have been responsible are, climate change or global warming and stresses persuaded by unplanned anthropogenic activities. It is to be stated that 'cloudburst' is defined as more than 100 mm rainfall per hour, suddenly occurring over a small area. The 'flash flood' is the fast and impulsive inundation, while the normal 'flood' is slower and more prolong that affect generally larger areas with steadily increasing water level. The constricted drainage system and narrow river valley have been attributed to the rainfall-triggered flash floods at many places. There has been cascading effect also due to earthquakes, (caused by plate convergence), to landslides to landslide-lake formation followed by its sudden rupturing to flash floods. It is the landscape and geomorphological features of the Himalaya that control the damage pattern during a catastrophe.

Several factors such as unauthorized civil constructions, non-abiding by building codes, erection of infrastructures in unscientific manner, exposure to vulnerable areas like river beds/banks, and lack of awareness, are attributed to the reasons of disasters. The youngest Uttarakhand (UK) state in the Indian Himalayan Region is ~85% mountainous, and has experienced flash floods and other geological cataclysms from time to time. To mention a few dreaded flash floods are, complete burst of Chorabari Lake leading to glacial lake outburst flood (GLOF) in 2013, Gangotri debris-flow that devastated a large area in 2017, ice-rock mass avalanche at Dhauliganga-Rishiganga catchment in 2021, snow-avalanches in Kedarnath and Hemkund Sahib in 2022, cloudburst events in Arakot-Uttarkashi (2019), Dharchula-Pithoragarh (2023) and Maldevta-Dehradun (2022), and rainfall triggered surge-type flash floods in Dharali-Uttarkashi (2025). The UK Himalaya has also witnessed disasters caused by rainfall-triggered 2003 landslides at Varunavrat Parbat in Uttarkashi, and massacre by earthquakes like Uttarkashi (1991) and Chamoli (1999) due to tectonic movement. Hence, we synthesize some key flash floods in the UK Himalaya to comprehend the reasons and provide their plausible remediation.

On 16th September 2025, Sahastradhara and surrounding areas of Dehradun, were ravaged by flash floods and landslides due to heavy rainfall or cloudburst. Several shops, hotels, homes and infrastructure were washed away or severely damaged, a few people went missing, popular tourist spot was flooded, and pathways were waterlogged. Again on 5th August 2025, a rainfall triggered landslides and massive mud-water flash floods in the Kheer Ganga river destroyed the Dharali village of Uttarkashi district, claiming 5 persons dead, 50 feared missing, several goats swept away, and many houses, shops, homestays and roads destroyed. The brunt of the massacre is also visible at nearby regions of Horsil and Sukhitop. The entire area in mountainous terrain is known for its scenic beauty. It is also the way to pilgrimage site and trekking route to Gangotri glacier and Gomukh, source for the Bhagirathi River. The higher Himalayan crystalline rocks, composed of gneisses, schists and migmatites, are highly weathered, fractured and jointed under the influence of cooling and warming phenomena. of climate variation. The glacio-fluvial deposits or loose debris materials, soaked with snow/glacier melt water, over the steep mountainous slope of more than  $>45^{\circ}$ ; rainfall at higher elevation; narrow valley with high inclines, created a surge-type flash flood by rapidly mobilizing the mud-water at downstream. However, the disaster was due to unregulated buildings in front of the Kheer Ganga river curve and construction on the alluvial fan and floodplain that disrupted the river's historical drainage path. Since the rainfall is shifting upward, the stations must be deployed at higher elevation for rainfall recording. We also need to look into high resolution drone-based and remote sensing data for establishing the fact of this disaster.

Another climate-surprise disaster in the UK Himalaya was heavy rainfall-triggered slope breakdown near Maldevta-Dehradun in August 2022. This smashed the channel and bank of Song and Baldi rivers for a 15 km stretch between Sarkhet and Thano, and completely eroded Sarkhet, Kumalta and lower portion of Maldevta town. It destroyed/washed away some huts and temporary stalls built on the banks of the river. The cloudburst in Arakot-Uttarkashi in August 2019 made double-impact as flash flood in Arakot nala and landslides at nearby region. This flash flood caused 19 people dead, 8 feared dead, and 15 injured, affected 38 villages covering an area of  $\sim 70$  km $^2$ , and stranded  $\sim 400$  people at various places. The Lasko valley in Pithoragarh district of UK state near Indo-Nepal border also witnessed rainfall-induced disaster in September 2022, which caused 6 fatalities, 11 reported missing, 72 houses severely damaged and more than 62 families deserted at